POTENTIAL GROUNDWATER MONITORING STATIONS
YAKIMA GROUNDWATER MANAGEMENT AREA

DECEMBER 3, 2013

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Prepared for:

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Lower Yakima Valley Groundwater Advisory Committee

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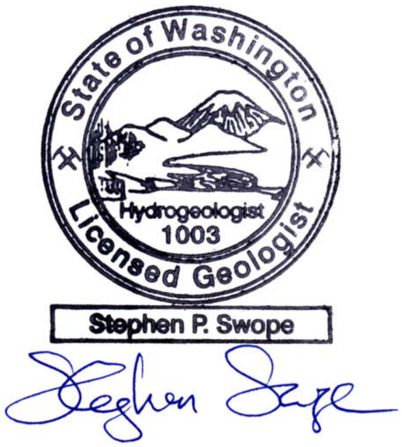
SIGNATURE

This report, and Pacific Groundwater Group's work contributing to this report, were reviewed by the undersigned and approved for release.



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1.0 EXECUTIVE SUMMARY

The purpose of this report is to present analysis of water quality trends, evaluation of spatial data gaps, and selection of monitoring stations for long term groundwater monitoring.

Nitrate data were provided to Pacific Groundwater Group (PGG) by Yakima County, who compiled data from the United States Geologic Survey (USGS), Yakima Health District, Valley Institute for Research and Education (VIRE), and Yakima County's own nitrate survey database. Additional data from the United States Environmental Protection Agency (EPA) were added by PGG but data from the area covered by the consent order between EPA and several dairies were not included. Data were imported into a consistently formatted water quality database to be submitted as an electronic deliverable to Yakima County. The WQ database contains nitrate results from 2,532 samples.

The WQ database includes geographic locations and a unique well ID for all nitrate samples, although the geographic locations are often approximate. Most nitrate samples also contain address locations.

Well depths are available for 63 percent of the samples and range from 1.17 feet in alluvium to 2,715 feet below ground surface in basalt. Half of the well depths are shallower than 136 feet. Nitrate concentrations are at or below the natural background level of 0.3 mg/L in 14.3 percent of samples. Nitrate concentrations exceed the GWMA-adopted water quality goal of 10 mg/L in 12.9 percent of samples. PGG evaluated the database, including use of statistics, to identify the number and distribution of monitoring stations, and the numbers of samples that are necessary to meet several of the GWMA monitoring objectives listed below:

- Fill spatial data gaps
- Monitor hot spots
- Track increasing concentration trends
- Measure basin-wide average concentration
- Monitor common water supply aquifers
- Measure effects of current and future practices
- Address health risks

Yakima County will visit the wells recommended by PGG through this evaluation, and verify conditions at the prospective monitoring stations. These visits will be combined with the Education and Outreach Committee's High Risk Well Assessment Survey. Wells that meet accessibility and construction criteria will be used as monitoring stations to meet each objective. Final design of the sampling programs to meet these objectives will be contained in a future deliverable scheduled for February 2014. The following paragraphs summarize analysis and recommendations for each objective:

Spatial Data Gaps: The largest five areas without nitrate data were identified as spatial data gaps. The areas range from 4.7 to 12.9 square miles. Existing wells were identified in those areas for field verification with the goal of identifying a single well in each area to serve as a monitoring station.

Hot Spots: PGG identified 71 “hot spots” with maximum nitrate concentrations in excess of 20 mg/L. Assuming an acceptance rate of 15 percent (owner acceptance, good physical conditions, etc.) to be verified by field visits, we expect to monitor approximately 15 percent of these hot spots (10 monitoring stations).

Increasing Trends: Of the 46 wells with at least 10 samples that have been collected over time, seven had a statistically significant increasing trend in nitrate concentrations, and nine had a statistically significant decreasing trend. The sample locations with increasing trends warrant monitoring because they are likely most to sensitive to land use changes, and may also pose a health risk if the increase is rapid enough. PGG thus recommends field verification and monitoring of the seven wells with increasing trend. All these wells are public water supply wells that are sampled for nitrate to meet WDOH requirements. As part of final evaluation of these stations, the GWMA will consider the frequency of monitoring conducted to meet WDOH requirements, frequency of monitoring necessary to meet GWMA objectives, and whether special QA/QC requirements imposed by the GWMA project dictate that the GWMA project collect its own samples.

Basin-Wide Average: PGG used the simple random approach to identify the number of monitoring stations that need to be sampled to measure the basin-wide-average at a level of confidence that supports use of the data for GWMA purposes. Those purposes include comparison of a current average to past and future averages, and comparison of averages to the GWMA-adopted water quality goal of 10 mg/L nitrate. The largest number of samples is required for a comparison of averages collected at different times. On the order of 1,000 samples appear to be necessary to confidently identify differences in basin-wide averages over time. That number of samples could be generated by a range of strategies; including sampling each of 170 to 250 stations four to six times over a year. PGG has provided Yakima County a list of wells to be field evaluated for use as future monitoring stations. Owner acceptance and physical conditions, to be confirmed through field verification, may limit the number of stations available to address this objective.

Common Water Supply Aquifers: The random sample set developed for the basin-wide average will likely include representative samples from common water supply aquifers. In addition, public water supply wells (sampled for WDOH) will be concentrated in these zones. Thus no separate set of wells was developed to address this objective. The ability of the basin-wide data set and WDOH water supply wells to monitor common water supply aquifers will be verified after the monitoring stations are selected.

Measure Effects of Current and Future Practices: Wells in the existing database are typically designed to supply drinking water not to reflect the effects of current or future nitrogen management practices. Many years or even decades of monitoring will be required to confidently distinguish changes in groundwater nitrate concentrations using existing wells. Thus quickly measuring the effects of current and future practices should not rely solely on wells in the existing database. Nitrate concentrations in specially designed water table monitoring wells (shallow wells) will currently reflect the effects of existing BMPs, and will respond much more quickly to future changes. Thus such wells are recommended to help meet this objective.

Specially designed shallow wells are recommended where BMPs are known to be changing. The number of wells and locations should be specified in a work plan generated at a time coordinated with changes to nitrogen management changes. To allow the wells to reflect recent historic practices as well as future practices, the wells should be installed as soon as appropriate locations can be identified. We therefore recommend allocation of budget to this work, and laying the groundwork for implementation.

Health Risks: Drinking water wells causing human health risks will be identified by Yakima County under a separate GWMA task. Based on that work, an unknown number of monitoring stations will be added to the monitoring network.

2.0 PURPOSE

The Lower Yakima Valley Groundwater Advisory Committee (GWAC), through Yakima County Public Services, selected HDR Engineering (HDR) and Pacific Groundwater Group (PGG) to perform two Scopes of Work under HDR contract #CON0082545. The first scope (led by HDR) is a study to identify applicable local, state, and federal regulatory requirements that control and manage nitrates in groundwater, identify Best Management Practices (BMPs), and evaluate the effectiveness of these BMPs. The second scope (led by PGG) focuses on development of a monitoring plan to evaluate changes in nitrate concentrations in groundwater.

This report describes methods used to select potential monitoring stations to be visited and inspected by Yakima Health District (YHD). The purpose of these YHD site visits is to complete the High Risk Well Assessment Survey and to verify the accessibility and suitability of the locations for long term monitoring (Field Verification).

In order to prepare a list of potential monitoring stations, PGG used the groundwater quality database developed for the Lower Yakima Valley Groundwater Management Area (GWMA) to characterize existing data, hereafter referred to as the WQ database (Section 3.2). Nitrate concentration trends are described in Section 5.0. In Section 6, PGG identifies existing wells for proposed for YHD field verification and future nitrate monitoring using well selection criteria listed in HDR contract #CON0082545. These wells are provided to the GWAC in an electronic database that is not reproduced as a table in this report. Specific tasks under the HDR contract covered in this report include:

- Task 1b (partial): Select potential monitoring stations for field verification; develop draft Field Verification Work Plan
- Task 2a: Water quality trend analysis
- Task 2b: Evaluate data gaps and provide recommendations on new sampling stations

This work was performed, and this report prepared, in accordance with hydrogeologic practices generally accepted at this time in this area. The resulting report is for the exclusive use of the Lower Yakima Valley Groundwater Advisory Committee, Yakima County, and HDR, for specific application to the Lower Yakima Valley.

3.0 DATA SOURCES

The following subsections describe three databases referenced in this report. The databases are linked through common data fields.

3.1 NITRATE WATER QUALITY DATABASE

A database was developed as part of this study to gather all groundwater nitrate data that had been collected to date. Sources of nitrate data provided by Yakima County (County) included the United States Geologic Survey (USGS), Yakima Health District (YHD), the Valley Institute for Research and Education (VIRE), and Yakima County's own nitrate survey database. Additional nitrate data from the United States Environmental Protection Agency (EPA) were added by PGG, but data from the area covered by the consent order between EPA and several dairies were not included. All data were imported into a consistently formatted water quality database.

3.2 WELL LOCATION DATABASE

A database of 7,790 domestic and public well locations and ownership information was developed as part of this study. This Well Location Database is used to propose potential monitoring stations (Section 6). Well location and ownership information for 7,695 domestic wells was provided by Yakima County, and was generated as part of the County's Nitrate Treatment Pilot Program. Well location and ownership information for 95 public water system wells were collected and added by PGG. PGG also supplemented the database with well depths from well logs where available.

3.3 INFORMATIONAL PUBLIC QUESTIONNAIRE, SURVEY #2

The Education and Public Outreach Working Group under the direction of the LYV GWAC created a 19-question survey to find out what residents served by private wells know about:

- Their drinking water and their opinion of its safety,
- Nitrate in groundwater, and
- The GWAC meetings.

The survey, conducted by Heritage University students during August and September of 2013, targeted eight areas and 300 households in the LYV GWMA (Lisa Freund, Yakima County, personal communication, 2013). The areas chosen were known to either have high nitrate in groundwater or were in areas where little data on nitrate levels exist.

Of the 300 households, 136 households responded to the survey, and 45 respondents (15 percent) agreed to be part of the more in-depth survey that includes water quality sampling for nitrate. These results will help determine where a second, more in-depth study of private wells in the Lower Yakima Valley should occur and the response percentages that could be expected from future surveys. The follow-up survey, which will include visits to proposed monitoring stations as described in section 5, is scheduled to take place later this year.

4.0 NITRATE CONCENTRATIONS IN THE LYV GWMA

The following table presents summary statistics for nitrate concentrations in the LYV GWMA, with non-detect values included at a value of half the detection limit. All nitrate concentrations in this report are milligrams nitrogen per liter (mg/L). A map showing monitoring well locations and sample locations is presented in Figure 1. Sample collection dates range from October 16, 1978 to March 5, 2013, although 85 percent of the samples were collected since 2000.

Statistic	Value
n(samples)	2,532
non-detect	375 (14.8%)
n(locations)	678
Minimum	0.03
Maximum	98.1
Mean	5.815
Median	4.7
Variance	51.78
Standard Deviation	7.196

Well depths are available for 428 of 678 locations (63 percent). Well depths range from 1.17[1] feet in alluvium to 2,715 feet below ground surface in basalt. Half of the well depths are shallower than 136 feet. Figure 2 indicates the distribution of well depths follows an approximately lognormal distribution.

Quality Assurance and Quality Control (QA/QC) data were not available for any of the data included in the WQ database, and 25 samples were excluded due to incomplete nitrate concentration values. The Groundwater Monitoring Quality Assurance/Quality Control Plan (PGG, 2013) indicates that data without associated QA/QC information not included in long-term monitoring data. However, the WQ data may be used for long-term monitoring point selection. The following sections characterize the nitrate data available for long-term monitoring point selection:

Data Distribution - The nitrate data with or without non-detect values do not follow a normal, lognormal, or gamma distribution and are therefore treated as non-parametric.

Comparison to Natural Background - According to the Ecology Preliminary Assessment (2010), "Concentrations above 0.3 mg/L indicate some process is leading to increased nitrogen in groundwater beyond what would be observed in a pristine watershed." A total of 363 of 2532 (14.3 percent) nitrate concentrations were detected or non-detect at or below the natural background level of 0.3 mg/L. Well locations where

[1] This well depth comes from the USGS NWIS database, and is listed as a well, not a spring, completed in alluvium. The information in the USGS NWIS database is generally considered to be of good quality.

the maximum value was at or below 0.3 mg/L are shown on Figure 3. Most of these wells cluster towards the edges of the GWMA.

Comparison to Ground Water Quality Criterion - The Washington State Groundwater Quality Criterion (GWQC) for nitrate is 10 mg/L. A total of 327 of 2,532 (12.9 percent) nitrate concentrations were detected above the GWQC of 10 mg/L.

Variability with Depth – Maximum nitrate concentration data are plotted in Figure 4 by three depth intervals: 0 to 100 feet, 100 to 200 feet, and greater than 200 feet. Geologic analysis to divide the dataset by aquifer was not performed. Where well depths are known, the three depth intervals generally divide the dataset into three equally-sized groups. Figure 4 shows that the wells where the maximum nitrate concentrations were at or below 0.3 mg/L tend to be completed at depths greater than 200 feet, with a cluster of wells with depths of 0 to 100 feet between Mabton and Sunnyside.

A boxplot of maximum nitrate concentration for each well location by well completion depth interval is presented in Figure 5. The boxplot shows that the mean and median nitrate concentration values generally decrease with depth up to 1,000 feet[2].

Depth Interval (feet below ground surface)	Number of Wells (n)	Mean[1]	Median[1]	Standard Deviation[1]
0 to 100	123	9.38	5.32	11.56
100 to 200	119	8.15	5.11	8.27
200 to 500	79	6.10	4.73	5.84
500 to 1000	19	3.88	1.30	4.39
Greater than 1000	22	3.92	1.50	6.16

[1] nitrate mg/L

Of the 22 sampled wells that are deeper than 1,000 feet, eight have maximum concentrations below 0.3 mg/L, 10 have maximum concentrations between 0.3 and 10 mg/L, and four have maximum concentrations above the GWQC of 10 mg/L.

5.0 NITRATE CONCENTRATION TRENDS

Concentration trends were evaluated on the entire nitrate data set over time, and for individual wells where time series data are available.

5.1 TREND FOR COMBINED DATASET

We evaluated the apparent long-term nitrate trend in the combined dataset by grouping maximum nitrate results per well location from the WQ database into five year periods (e.g. 1980 to 1984, 1985 to 1989), and making comparison between the groups. A list of statistics for each five year period is presented below. The median and number of high nitrate concentration values have increased over time; however, a bias toward an

[2] Possible outliers were not identified or removed prior to calculating these statistics.

increasing trend could be as a result of more recent sampling programs targeting shallower wells that are more subject to nitrate contamination; whereas older data tends to be from deeper water supply wells that were routinely sampled to meet WDOH drinking water monitoring requirements. Evaluations using data from individual wells, discussed in the following subjection, are not subject to this bias and should be favored as a measure of trend in the GWMA.

Date Range of Well Samples	Number of Wells (n)	Mean Nitrate[1]	Median Nitrate[1]	Standard Deviation[1]
1975 to 1979	4	1.45	1.10	1.66
1980 to 1984	51	3.48	1.70	4.10
1985 to 1989	40	3.33	1.80	3.63
1990 to 1994	76	3.52	2.60	3.89
1995 to 1999	69	4.06	3.90	3.29
2000 to 2004	295	6.36	4.00	8.56
2005 to 2009	90	4.74	4.44	3.60
2010 to 2014	323	13.51	11.50	11.17

[1] nitrate mg/L

5.2 MANN-KENDALL TREND TEST FOR INDIVIDUAL WELLS

Forty-six wells had more than 10 samples over time and were therefore evaluated for individual trends (Figures 6 through 15). All sample locations were public water system wells with data from the WDOH Sentry database. Quality Assurance and Quality Control (QA/QC) information was not available for the WDOH dataset, but cursory inspection suggests there are QA/QC issues with these data. For example, on Figure 10, Station 2897016 shows anomalously high variability in nitrate concentrations between samples.

The wells for which time-series data are available tend to be deeper than average, with a median depth of 342 feet compared to 136 feet for all wells. Therefore, although free of the type of bias that may be present in the grouped data discussed in Section 5.1, they may not reflect trends in shallower wells.

PGG identified wells with statistically significant trends using the Mann-Kendall trend test (Table 1). The Mann-Kendall test is a nonparametric trend test which uses ranks instead of concentration values. The Mann-Kendall trend test results for wells with upward trends are presented below. Statistical significance can be affected by outlier values; outliers were not identified or removed as part of this analysis.

Results show 16 statistically significant trends, 7 upward and 9 downward. Locations where statistically significant upward trends occur are listed below and are shown in Figure 17. An upward trend is indicated by a positive tau and a significant trend is indicated by a p of less than 0.05. Wells with upward trends are widely spread through the GWMA, although 3 wells cluster near Grandview. The similarity in number of upward and downward trends suggests an absence of strong uniform trend throughout the GWMA.

Well ID	number of samples (n)	Std dev	p	tau	Up/ Down	Location
2897001	32	3.63	7.0E-03	0.34	Up	Grandview
2897010	139	4.67	1.1E-06	0.28	Up	Grandview
2897011	29	1.24	2.8E-02	0.29	Up	Grandview
6494002	21	1.62	3.4E-03	0.47	Up	Outlook Elem School
6591901	37	3.37	2.7E-02	0.26	Up	Panorama Place Water Assn
8540005	12	0.98	1.9E-02	0.53	Up	City of Sunnyside
AB70001	10	4.34	1.2E-02	0.64	Up	Wineglass Cellars

std dev = standard deviation; p = statistical significance; Tau = test statistic; Trend considered significant for p<=5.0E-02 (0.05)

6.0 IDENTIFICATION OF POTENTIAL SAMPLING STATIONS

PGG developed a list of potential monitoring stations (provided to Yakima County electronically as a database) using well selection criteria listed in HDR contract #CON0082545. PGG used two databases, the nitrate WQ database and the Well Location database described above to select stations using the criteria listed below and further described in Subsections 6.1 through 6.7:

1. Spatial data gaps – Investigating spatial data gaps will identify whether additional hot spots exist. Monitoring stations are proposed for the largest 5 areas where no existing nitrate information is available. Spatial data gaps were selected by measuring the distance between all known nitrate concentrations.

2. Hot spots - Monitoring well stations are proposed at or near wells with maximum nitrate concentrations equal or greater than 20 mg/L (or twice the GWCL of 10 mg/L) to achieve the objective of monitoring groundwater quality and change over time.

3. Increasing concentration trends – Monitoring well stations are proposed at or near wells with statistically significant increasing nitrate trends. These wells will likely be among the first to show changes in nitrate concentration.

4. Basin-wide monitoring - Monitoring well stations are proposed using a simple random selection process with sample size large enough to achieve a confident comparison of baseline average to future average nitrate concentration.

5. Common water supply aquifers - Monitoring well stations proposed for the basin-wide monitoring will likely include representative samples in common water supply aquifers. This will be verified by comparing the depth profile of the basin-wide monitoring locations to the depth profile of all wells.

6. Measure Effects of Current and Future Practices (Best Management Practice (BMP) effectiveness) - Monitoring is recommended in water table (shallow) wells constructed specifically for this purpose. Specifics should be proposed in a subsequent work product.

7. Health risks- Drinking water wells causing human health risks will be identified by Yakima County under a separate GWMA task.

Several of the subsections below refer to “field verification.” Yakima County will evaluate numerous possible wells identified by PGG for possible future use as a GWMA monitoring station. Those wells that are made accessible by owners and are physically accessible to field staff will be used for future monitoring. We anticipate additional well depth information will be gathered during field verification. A single well may be used to meet more than one objective.

This report identifies numbers of wells targeted for sampling but does not propose specific sampling strategies to meet the objectives. Sampling strategy will be provided in the Monitoring Plan that will be submitted to the GWAC as a subsequent task.

6.1 SPATIAL DATA GAPS

PGG identified the 5 largest areas within the GWMA without nitrate data, but where wells are available for monitoring. Using ArcGIS software, we mapped the distance from every point in the LYV to existing wells with nitrate sample data or the GWMA boundary, whichever was closer; then used the minimum distance map to find the five largest areas (Figure 16). The areas range from 4.7 to 12.9 square miles.

Only the five largest areas were selected because there appeared to be a break in size between the next smallest data gap area. Due to the low response rate and incomplete well depth information, well depth was not accounted for in the spatial data gaps analysis.

Within the five areas there are 215 possible monitoring wells. Based on a response rate of 15 percent (as achieved by the YHD Health Survey), there should be a sufficient number of wells to select one monitoring well for each spatial data gap. For the purpose of the upcoming survey, wells were ranked for each of the 5 areas based on proximity to the centroid of the spatial data gaps. And for each of the 5 areas, 10 wells were provided to the LYV GWAC for field surveying.

6.2 HOT SPOTS

PGG identified 71 wells with maximum nitrate concentrations equal or greater than 20 mg/L, a concentration twice the GWCL of 10 mg/L (chosen to define a “hot spot”). See Figure 4 for nitrate concentrations by well depth and Figure 17 for a summary of well locations where maximum nitrate is greater than 20 mg/L.

Those wells that are made accessible by owners and are physically accessible to field staff will be used for future monitoring. Assuming an acceptance rate of 15 percent, approximately 10 of these wells may be available as future monitoring stations.

6.3 INCREASING CONCENTRATION TRENDS

PGG identified 7 wells with upward trends using the Mann-Kendall trend test as described in Section 5. Despite some irregularities in the data for some of these 7 wells, all 7 wells will be retained as future monitoring stations if they remain available.

As noted above, none of the existing data include QA/QC data, however, the Groundwater Monitoring Quality Assurance/Quality Control Plan (PGG, 2013) allowed for continued use of WDOH data. WDOH requires that Group A and B public water supply systems sample for nitrate, regardless of sampling performed to meet the GWMA objectives. Thus the GWMA may continue to rely on data gathered within the WDOH program.

Many years to decades may be necessary to confidently detect changes in nitrate concentration in wells typical of the existing database, and additional supply wells added through field verification. The long time frames are caused by slow groundwater flow rates and variability which obscures actual change (signal to noise). For these and other reasons, monitoring for BMP effectiveness should not rely solely on water supply wells. Monitoring of specially designed and sited water table monitoring wells (shallow wells) is recommended to determine levels and trends in nitrate concentrations. They will respond much more quickly to local land use change than deeper and more variable wells in the WQ database and Well Location database.

6.4 BASIN-WIDE MONITORING

PGG used the simple random approach to identify the number of monitoring stations that would need to be sampled to measure the basin-wide-average at a level of confidence that supports use of the data for future GWMA purposes. Those purposes include comparison of a current average to past and future averages, and comparison of averages to the GWMA-adopted water quality goal of 10 mg/L nitrate. The largest number of samples are required for a comparison of averages collected at different times. To meet that objective, PGG estimates on the order of 1,000 samples would be required. That number of samples could be generated by a range of strategies – including sampling each of 170 to 250 stations four to six times over a year. Owner acceptance and physical conditions, to be confirmed through field verification, may limit the number of stations available to address this objective.

Target well locations for field verification were identified using a simple random sampling plan. Simple random sampling means that each of the 7,790 well locations has an equal chance of being one of the selected measurements a future monitoring station. This method is used for estimating means, medians, and trends when the population does not in general contain major trends, cycles, or patterns, which appears to be a valid assumption in this case. With this sampling method, a large number of samples are necessary to confidently identify changes in the basin-wide average nitrate concentration between baseline and data sets collected after land use change.

The simple random method assumes that the sampling frame, which is our master list of well locations in the Well Location database, is a complete list for the GWMA or is representative of the entire population of wells in the GWMA. If the sampling frame is grossly incomplete or biased, a random sample of wells from the Well Location database may be biased relative to the entire population of wells.

Only 15 percent of well owners agreed to have their wells sampled when approached by YHD (Section 3.1). A high nonresponse rate may result in a biased well monitoring network if the nonrespondent wells differ systematically from the respondent wells. For example, if private well owners are highly nonresponsive, but public water system well owners are responsive, the resultant monitoring network could be biased as to location, depth, or nitrate concentration. Since the response rate is expected to be low, the final monitoring well network will be compared to the simple random sample target well list to evaluate for bias in well owner type, well depth, or well location.

6.5 COMMON WATER SUPPLY AQUIFERS

The simple random sampling plan as described above will also be used to identify stations to monitor common water supply aquifers. The random sample will likely include a representative sample of well depths, and a representative sample of common water supply aquifers. This assumption will be verified after the final monitoring stations are selected.

6.6 MEASURE EFFECTS OF CURRENT AND FUTURE PRACTICES (BMP EFFECTIVENESS)

Wells in the existing database are typically designed to supply drinking water not to reflect the effects of current or future nitrogen management practices. Many years or even decades of monitoring will be required to confidently distinguish changes in groundwater nitrate concentrations using existing wells. Thus quickly measuring the effects of current and future practices should not rely solely on wells in the existing database. Nitrate concentrations in specially designed water table monitoring wells (shallow wells) will currently reflect the effects of existing BMPs, and will respond much more quickly to future changes. Thus such wells are recommended to help meet this objective.

Specially designed shallow wells are recommended where BMPs are known to be changing[3]. The number of wells and locations should be specified in a work plan generated at a time coordinated with changes to nitrogen management changes. To allow the wells to reflect recent historic practices as well as future practices, the wells should be installed as soon as appropriate locations can be identified.

6.7 HEALTH RISKS

Areas of elevated human health risk will be identified using results of the Education and Outreach Committee's High Risk Well Assessment Survey. Factors such as presence of a seal, number of affected population served, nitrate concentration will be used to evaluate

[3] In future phases of this project, changes to BMPs will be made to reduce the release of nitrate to groundwater. The shallow water table below locations where these changes are made will likely show the most rapid changes in nitrate concentration.

human health risk. This evaluation will be performed in association with the WDOH. The number of wells monitored will depend on the number of responses to the survey.

7.0 REFERENCES

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Table 1. Mann-Kendall Trend Test Results

Well ID	n	Standard Deviation	p, Statistical Significance	Tau	Significant Trend? (Up/Down)
4965001	158	3.757434616	2.36E-15	-0.44383	Down
4965004	78	1.89009415	5.65E-07	-0.4372	Down
628702	55	4.538235117	2.37E-06	-0.43898	Down
9980003	17	0.922267825	0.001970103	-0.56298	Down
AA43202	56	3.188313314	0.014880689	-0.22617	Down
2897008	17	2.190488295	0.018875547	-0.42647	Down
415701	18	0.953212148	0.025326289	-0.39344	Down
2897016	102	5.180332219	0.042952381	-0.13641	Down
1624202	17	3.084524942	0.043545581	-0.36765	Down
2897010	139	4.66576742	1.09E-06	0.280523	Up
6494002	21	1.621034502	0.003399434	0.466667	Up
2897001	32	3.630838346	0.007041277	0.339095	Up
AB70001	10	4.343853896	0.012266059	0.644444	Up
8540005	12	0.97557287	0.019440878	0.534367	Up
6591901	37	3.371602995	0.027055988	0.255639	Up
2897011	29	1.242397174	0.0281302	0.291359	Up
8540008	19	1.206685083	0.057831056	0.327433	
3035001	10	2.545829705	0.063697524	0.50128	
9980001	28	1.436279871	0.065804727	-0.25067	
4965002	21	3.665686709	0.074193016	0.288475	
2241801	12	1.617658943	0.080057926	0.413167	
8512101	17	0.673063125	0.083351925	0.317345	
2897017	12	9.085462372	0.086471118	0.393939	
6618501	14	0.994219833	0.188887477	-0.27473	
4965003	95	3.14459843	0.197246656	0.090287	
3430101	16	0.825814497	0.206981122	0.24268	
8540009	21	1.239719054	0.213335901	0.218521	
359401	11	0.421730202	0.241476879	-0.29359	
1624201	20	3.620006397	0.269223869	0.185682	
2897007	110	3.727389015	0.29422757	-0.06812	
6990001	23	1.6916734	0.340254098	0.148011	
2897012	13	1.680576061	0.360121638	-0.20513	
9191301	46	4.239114351	0.399168849	0.087337	
2897014	22	0.09500057	0.472785711	-0.1341	
2897003	30	0.664776257	0.475308478	-0.09447	
2959701	18	0.562694556	0.517352164	0.140028	
628701	23	1.12963739	0.52119571	0.102968	
AA48401	13	3.627026754	0.624854445	-0.11613	
8540006	23	0.305602496	0.631960332	-0.08802	
2897013	80	2.64923693	0.644453287	-0.03751	
2897002	34	2.18098009	0.667067051	-0.05372	
8540007	25	1.154570627	0.766732275	-0.05238	
430201	15	1.544543391	0.804336071	-0.05742	
477601	16	5.74453969	1	-0.00837	
2900001	21	0	1	1	
9980002	17	0.764660632	1	0.015401	

stdev = standard deviation
p = statistical significance
Tau = test statistic
Trend considered significant for p<=0.05

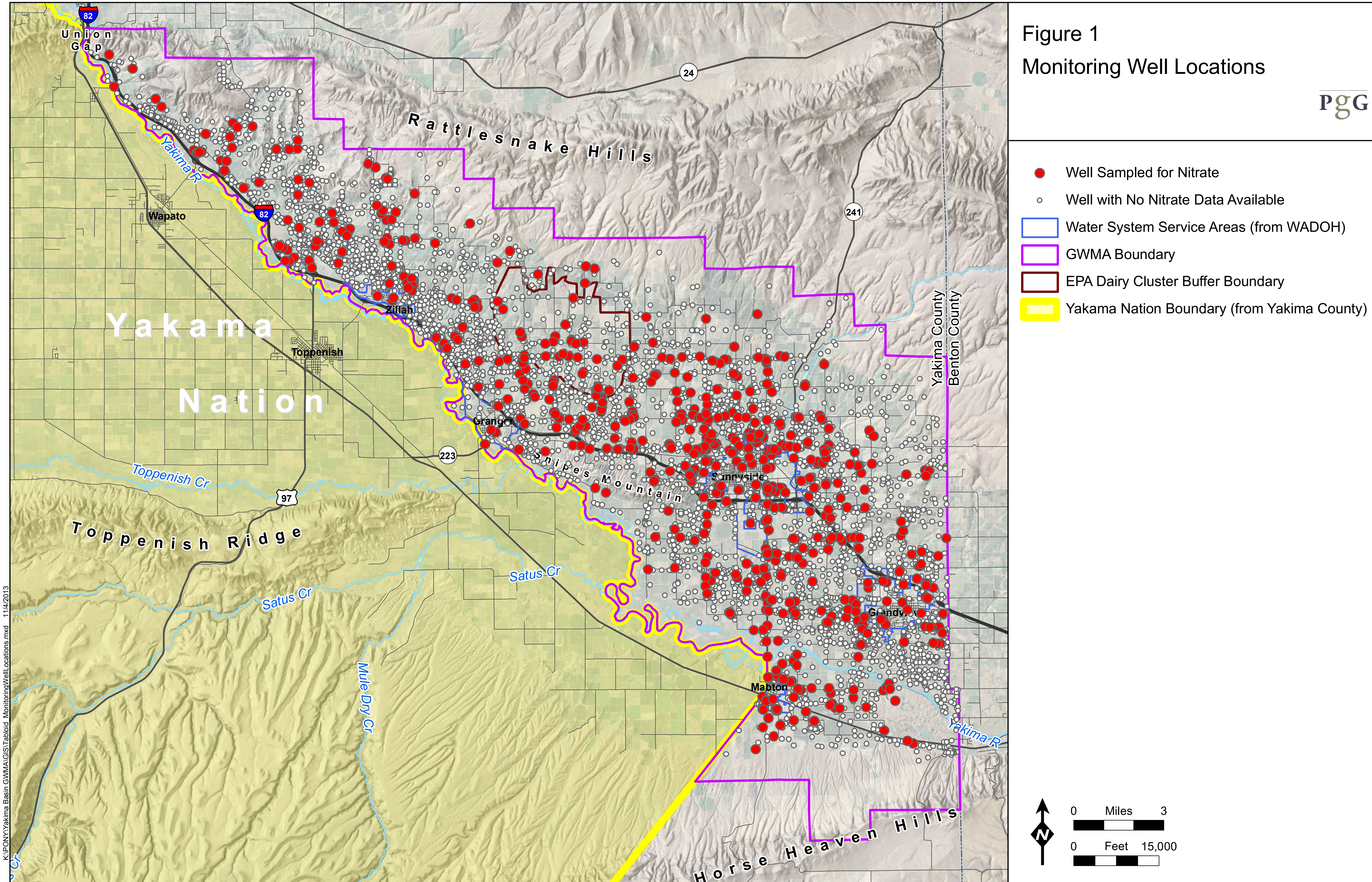
Figure 1
Monitoring Well Locations
PgG
Well Sampled for Nitrate
Well with No Nitrate Data Available
Water System Service Areas (from WADOH)
GWMA Boundary
EPA Dairy Cluster Buffer Boundary
Yakama Nation Boundary (from Yakima County)
Union Gap
Rattlesnake Hills
Yakima R
Wapato
Zillah
Toppenish
Yakama Nation
Granger
Snipes Mountain
Sunnyside
Toppenish Cr
Toppenish Ridge
Satus Cr
Satus Cr
Mule Dry Cr
Mabton
Grandview
Yakima County
Benton County
Yakima R
Horse Heaven Hills
82
24
241
223
97
N
0 Miles 3
0 Feet 15,000
K:\PONY\Yakima Basin GWMA\GIS\Tabloid_MonitoringWellLocations.mxd 11/4/2013

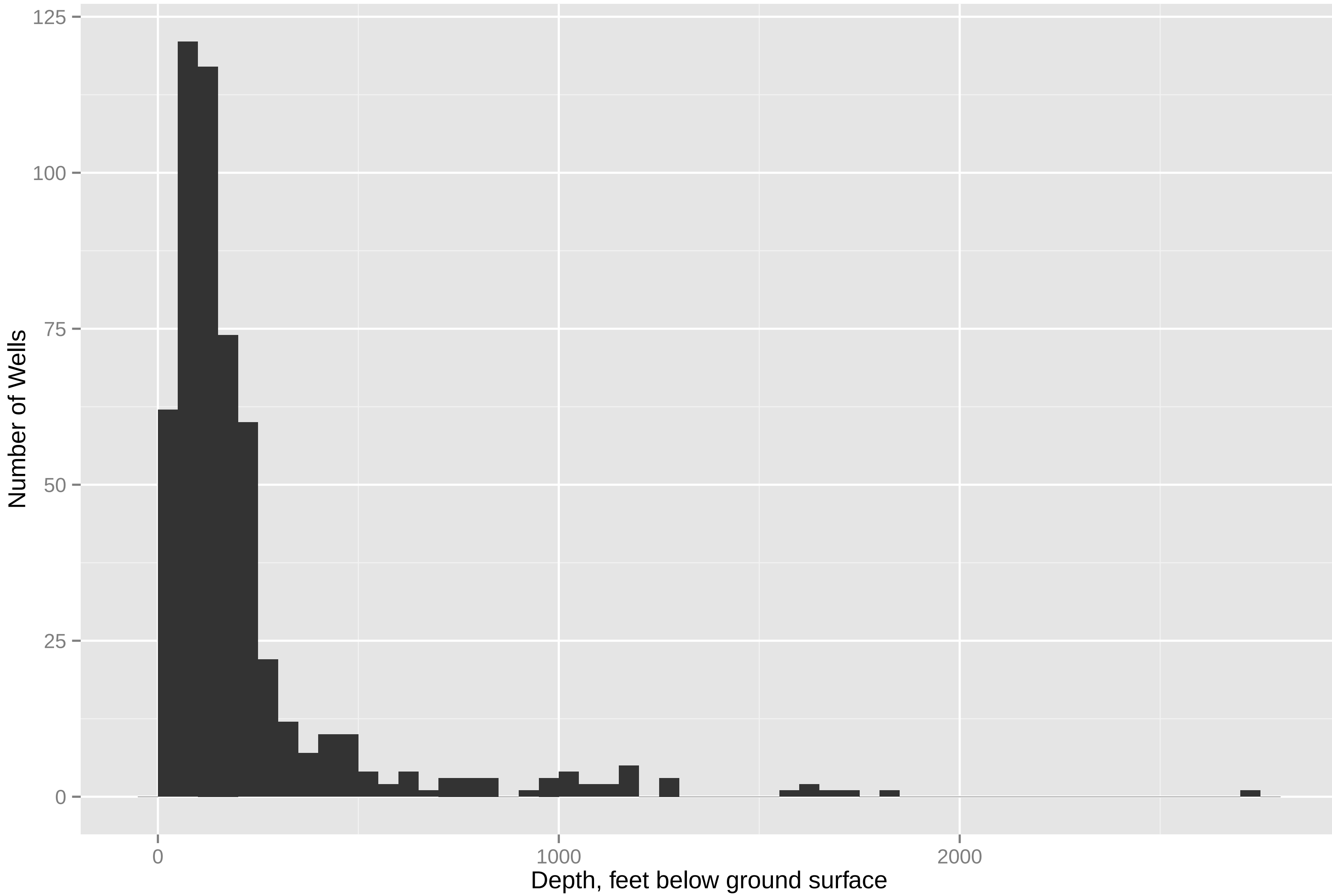

Figure 2. Well Depth Histogram

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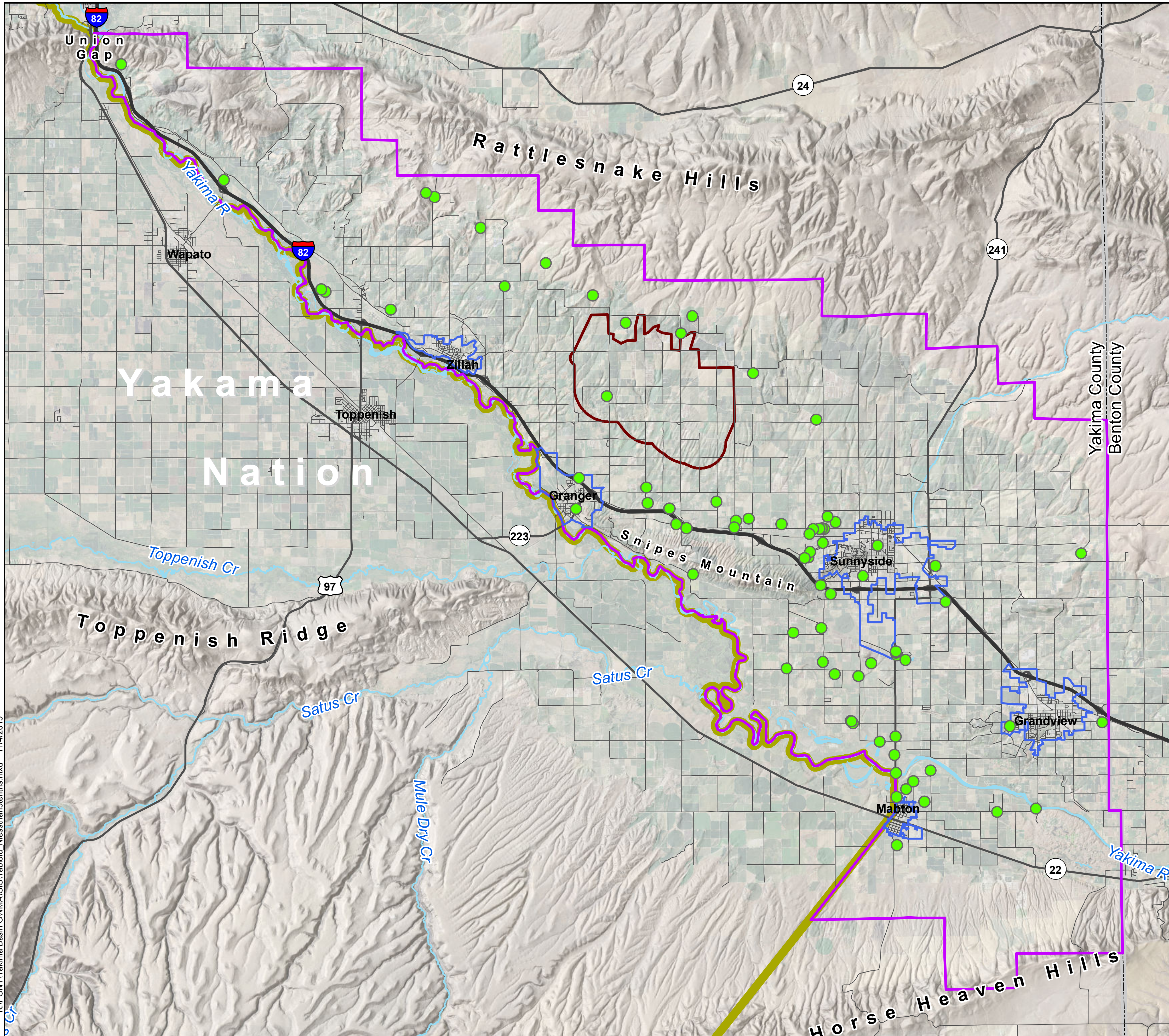
PgG

Figure 3

Nitrate Concentrations less than 0.3 mg/L



- Wells Sampled with Nitrate < 0.3mg/L*
- Water System Service Areas (from WADOH)
- GWMA Boundary
- EPA Dairy Cluster Buffer Boundary
- Yakama Nation Boundary (from Yakima County)

*Wells with Non-Detects are mapped at half the reporting limit

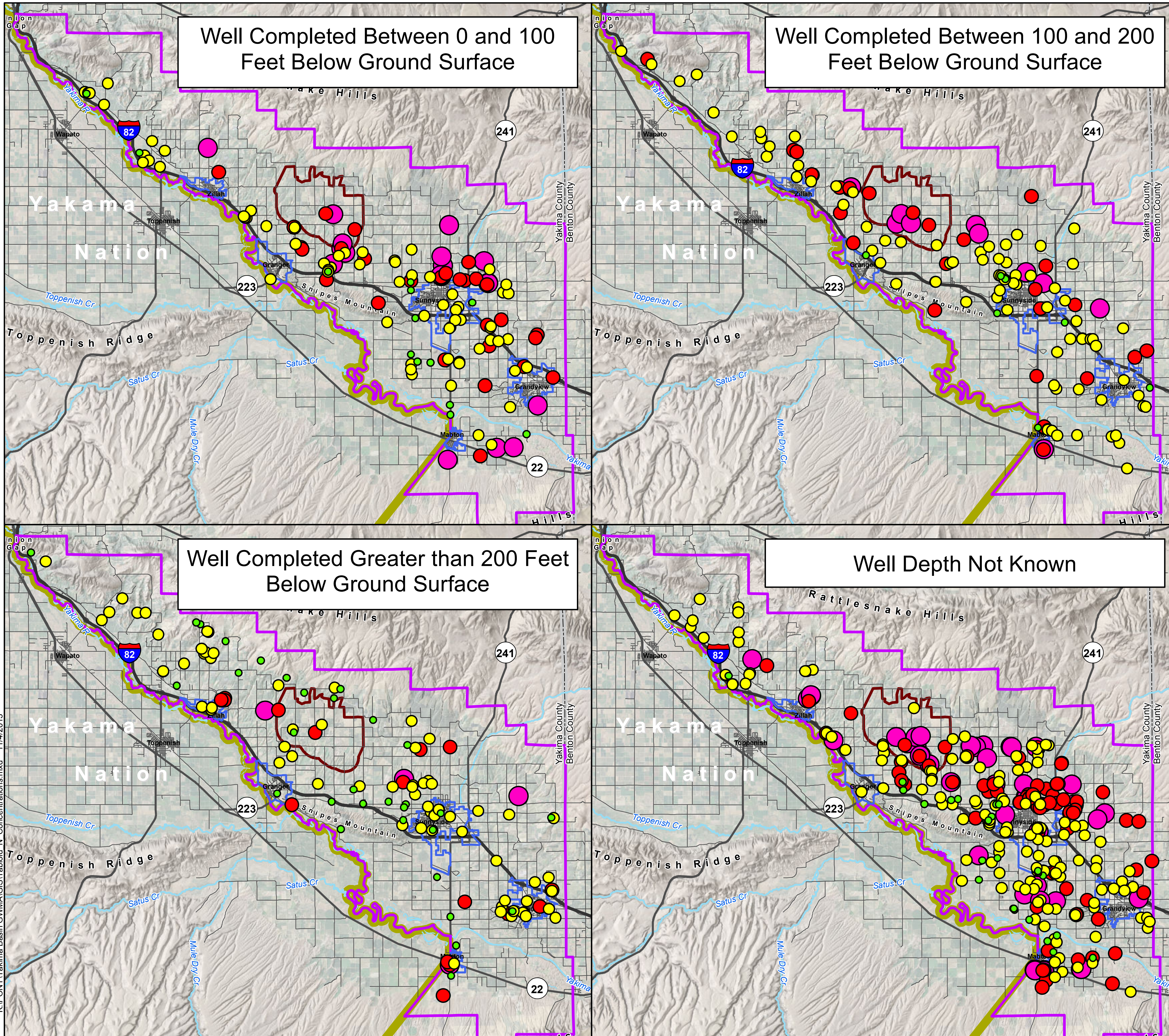
0 Miles 3

0 Feet 15,000

K:\PONY\Yakima Basin GWMA\GIS\Tabloid_Nlessthan3tenths.mxd 11/4/2013

Figure 4
Nitrate Concentrations by Well Depth

PGG



Maximum Nitrate Concentration Result*

- <= 0.3 mg/L
- 0.4 - 10.0 mg/L
- 10.1 - 20.0 mg/L
- > 20.1 mg/L
- Water System Service Areas (from WADOH)
- GWMA Boundary
- EPA Dairy Cluster Buffer Boundary

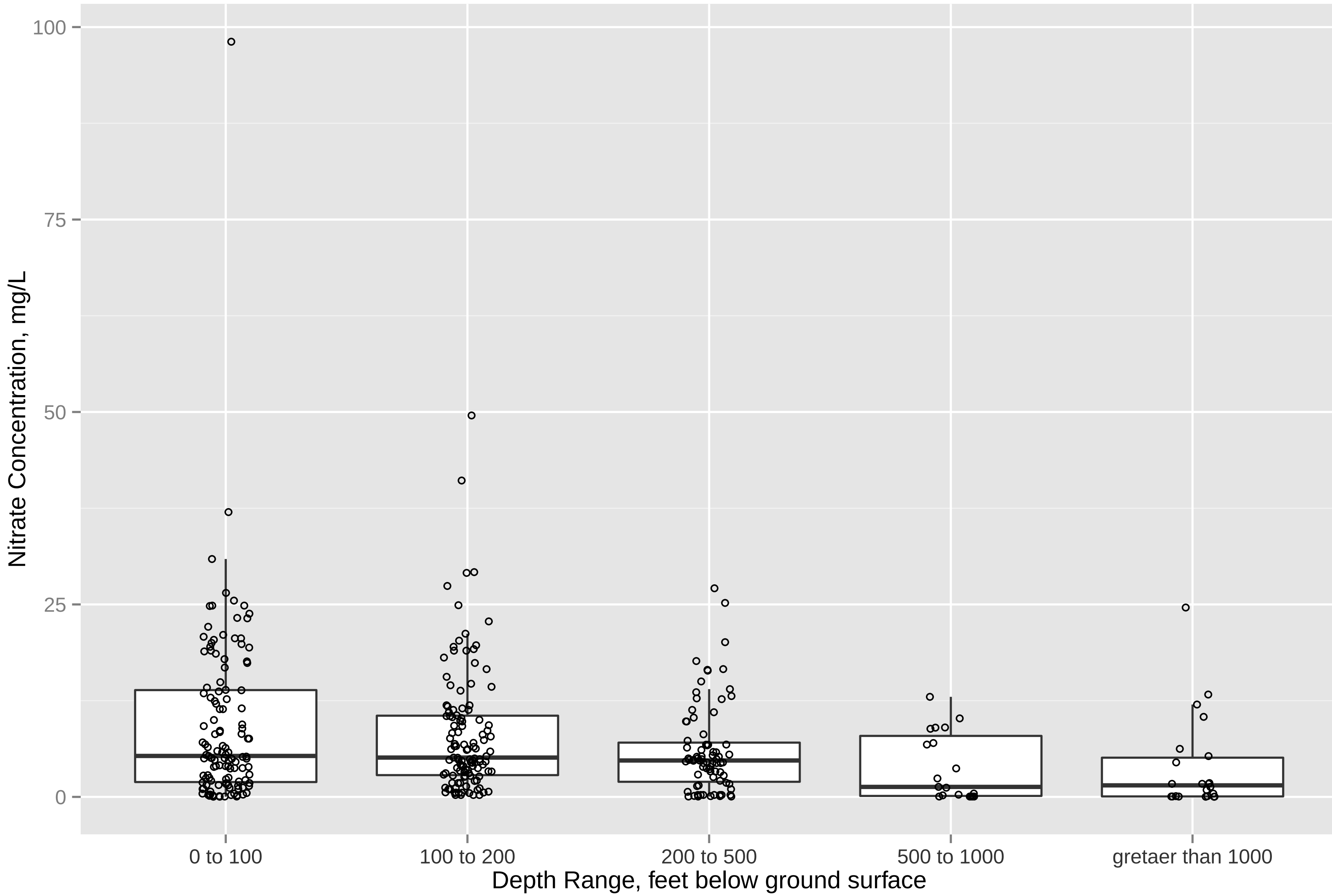
*Wells with Non-Detects are mapped at half the reporting limit

N

0 Miles 5

0 Feet 25,000

K:\PONY\Yakima Basin GWMA\GIS\Tabloid_N_Concentrations.mxd 11/4/2013



Non−detect values plotted at half the Method Reporting Limit value
black open circles represent actual data points, shifted in position to avoid directly overplotting other points
Maximum value selected for each well location

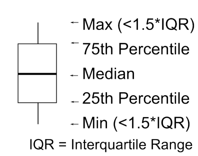


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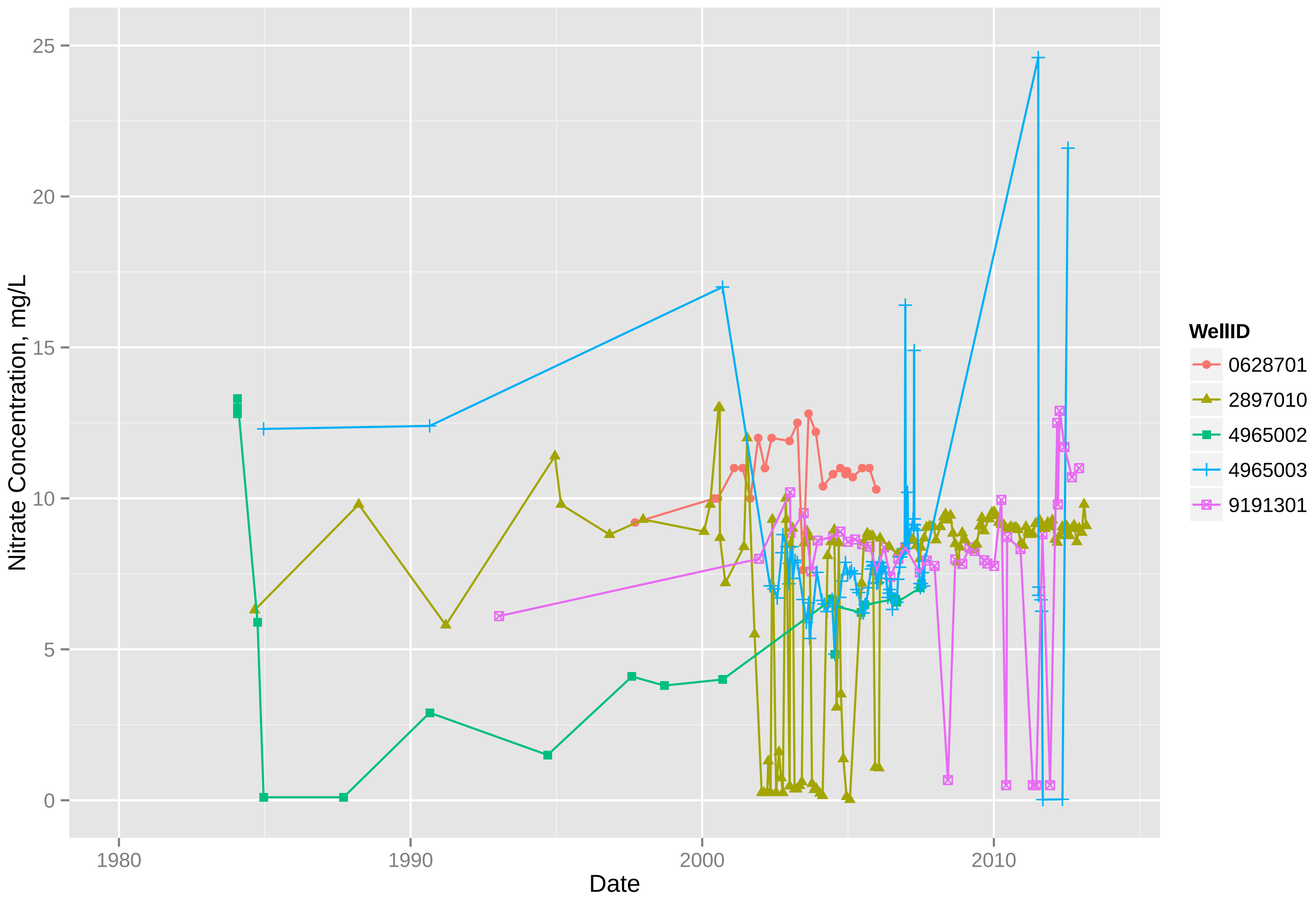
Figure 5. Boxplot of Max Nitrate by Well Depth



Non−detect values plotted at half the Method Reporting Limit value

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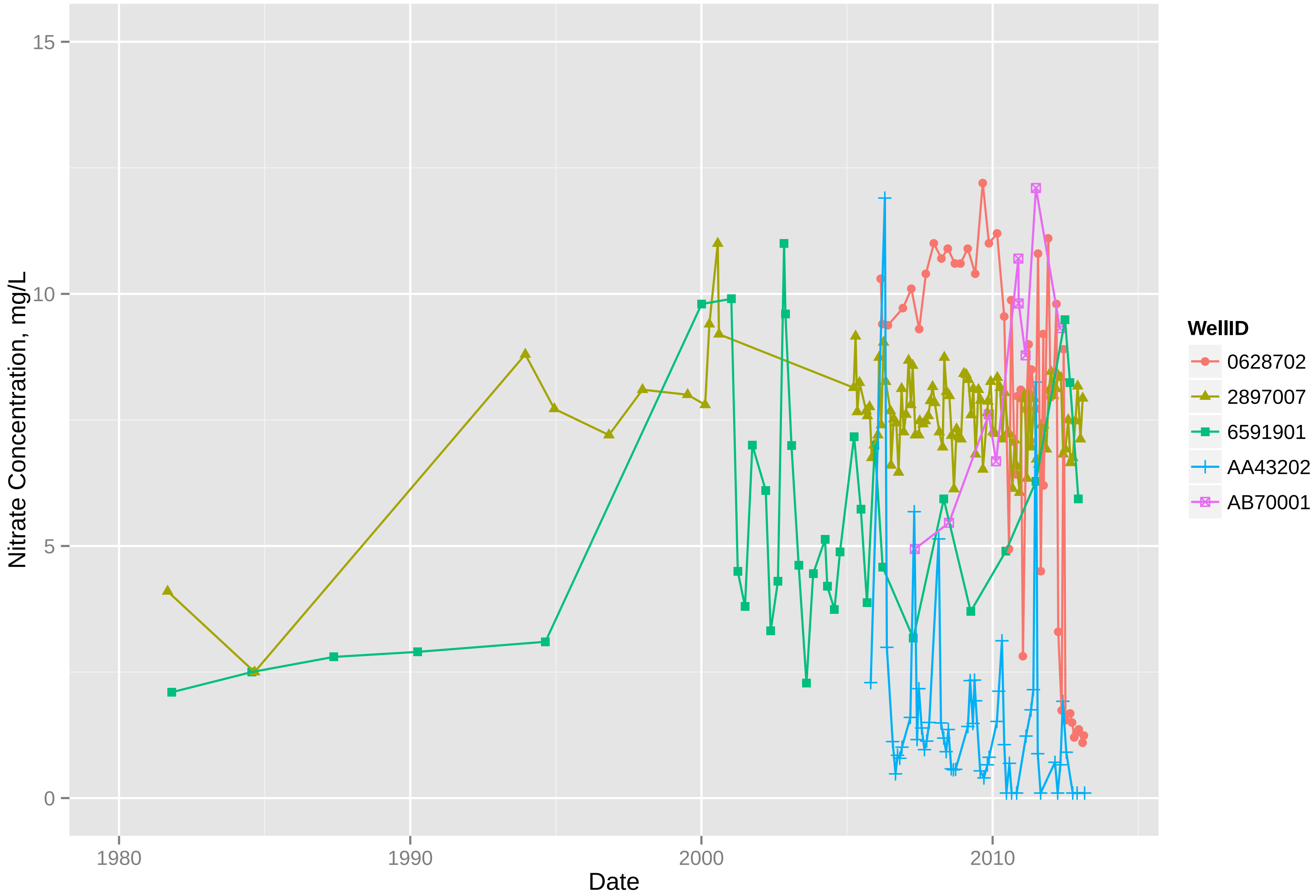
Figure 6. Nitrate Times Series

Max Nitrate >12.5 mg/L

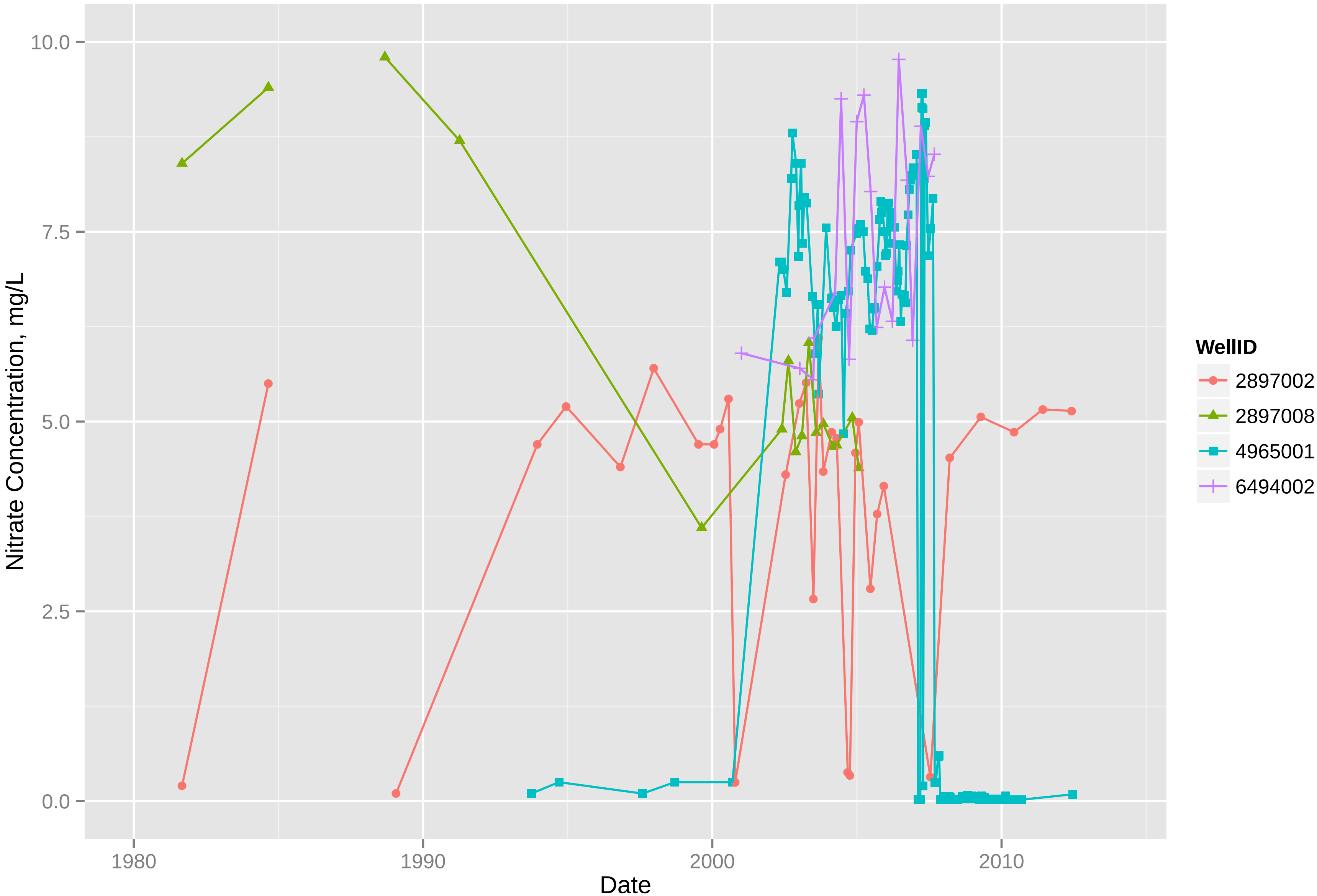
PgG



Non−detect values plotted at half the Method Reporting Limit value

Prepared 12/03/2013

Figure 7. Nitrate Times Series
Max Nitrate 11 to 12.5 mg/L



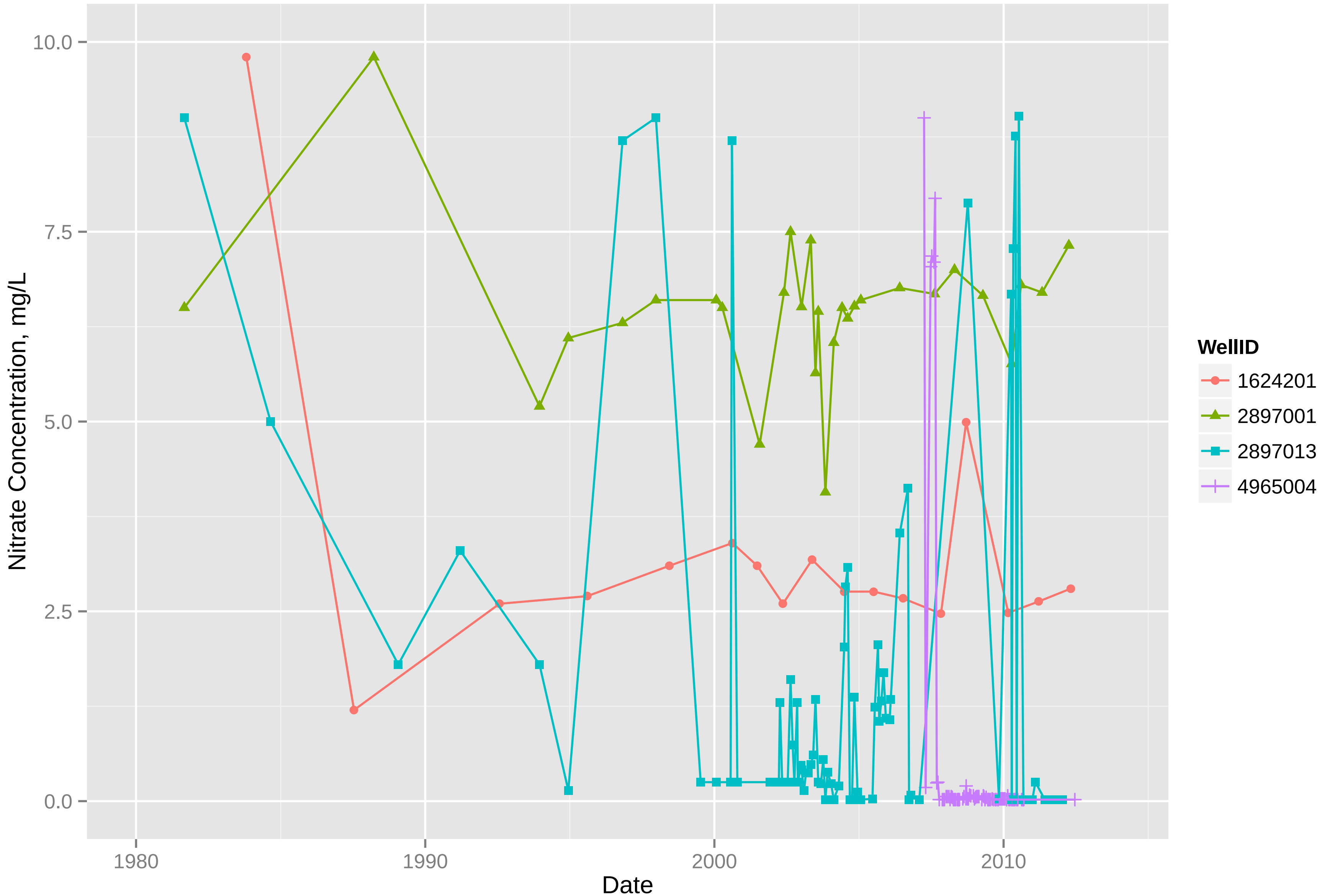
Non−detect values plotted at half the Method Reporting Limit value

Prepared 12/03/2013

Figure 8. Nitrate Times Series

Max Nitrate 10 to 11 mg/L

PgG

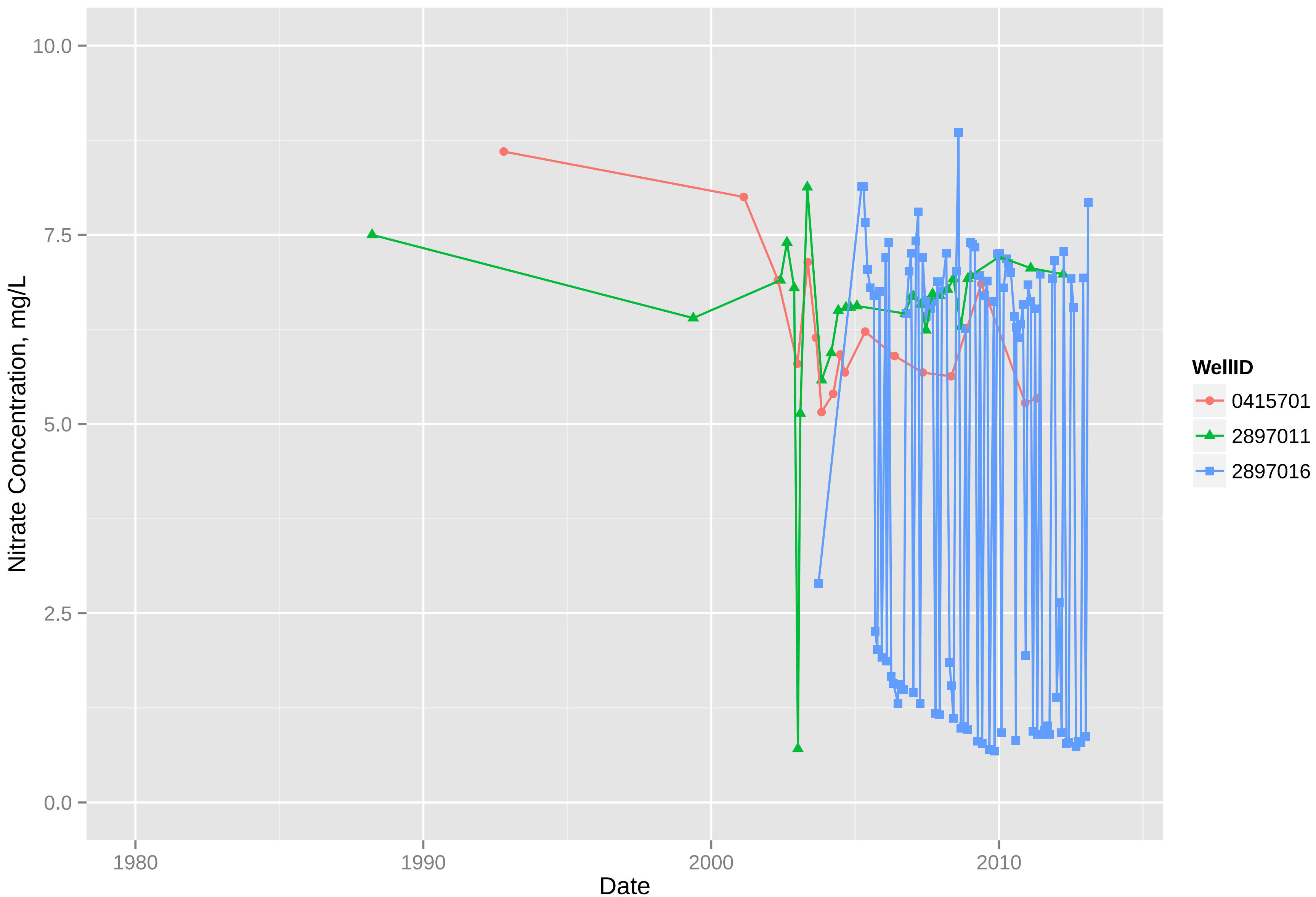


Non−detect values plotted at half the Method Reporting Limit value

Prepared 12/03/2013

Figure 9. Nitrate Times Series

Max Nitrate 9 to 10 mg/L



Non−detect values plotted at half the Method Reporting Limit value

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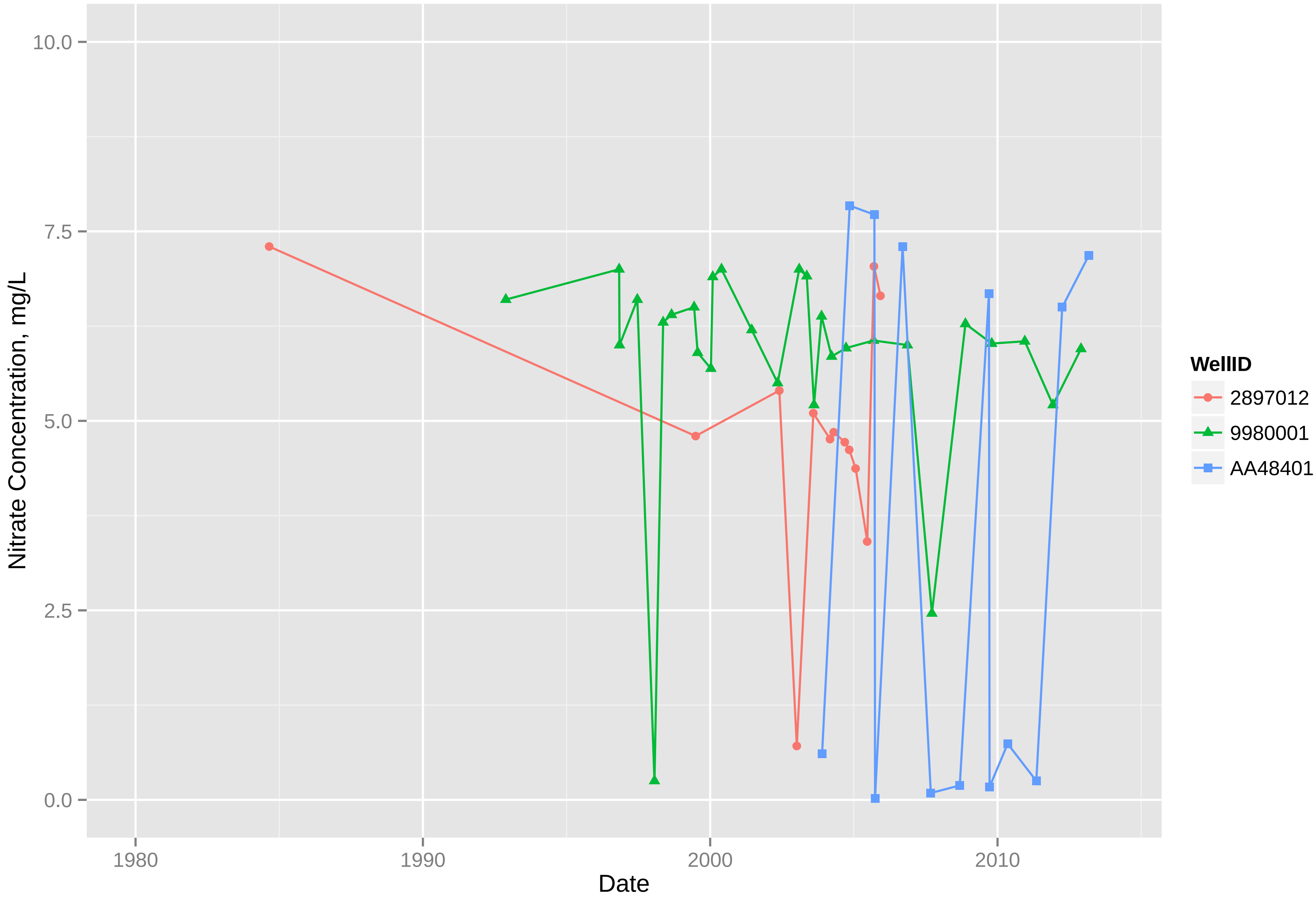
Figure 10. Nitrate Times Series
Max Nitrate 8 to 9 mg/L

PgG



Non−detect values plotted at half the Method Reporting Limit value

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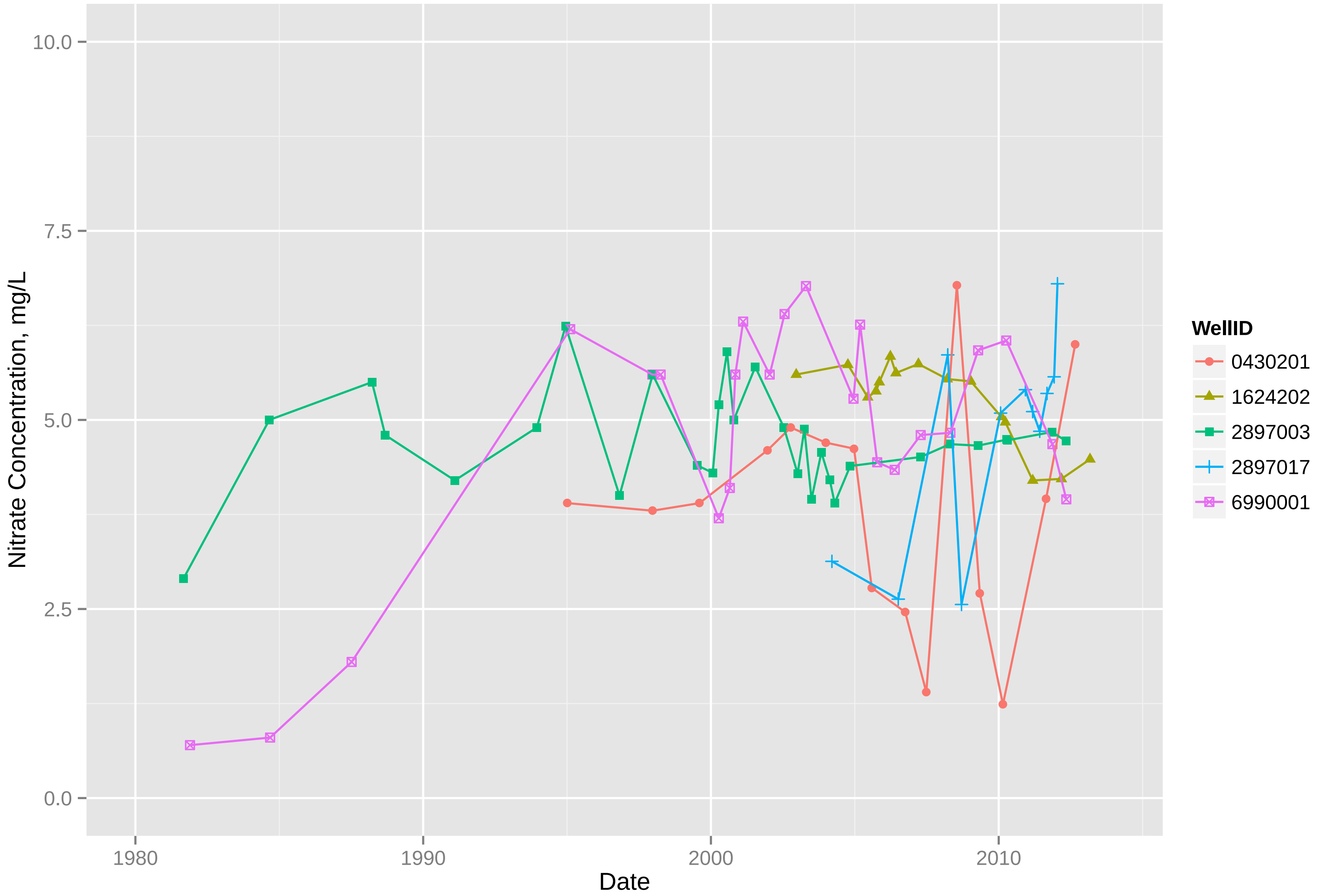
Figure 11. Nitrate Times Series

Max Nitrate 7 to 8 mg/L

PgG



Non−detect values plotted at half the Method Reporting Limit value

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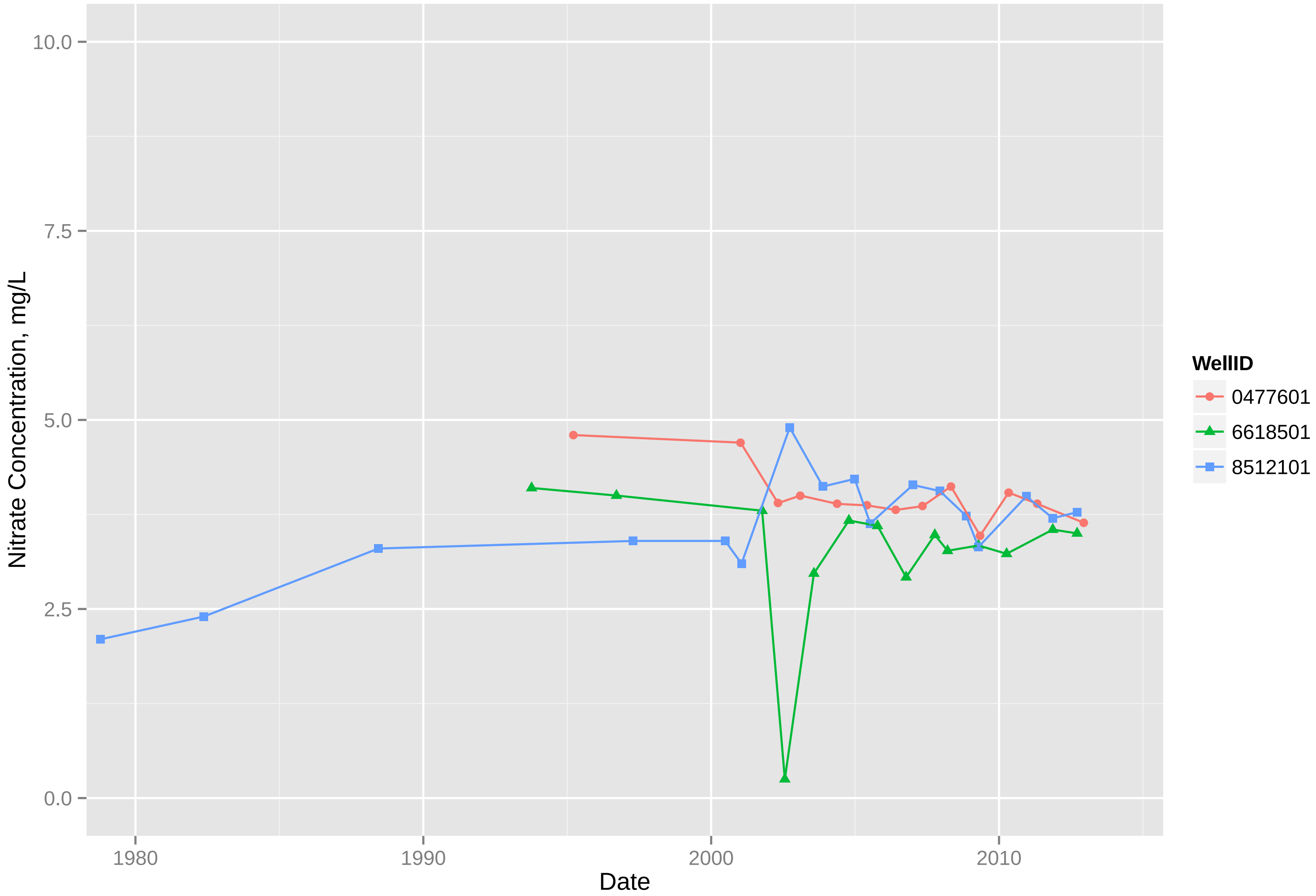
Figure 12. Nitrate Times Series

Max Nitrate 5 to 7 mg/L



Non−detect values plotted at half the Method Reporting Limit value

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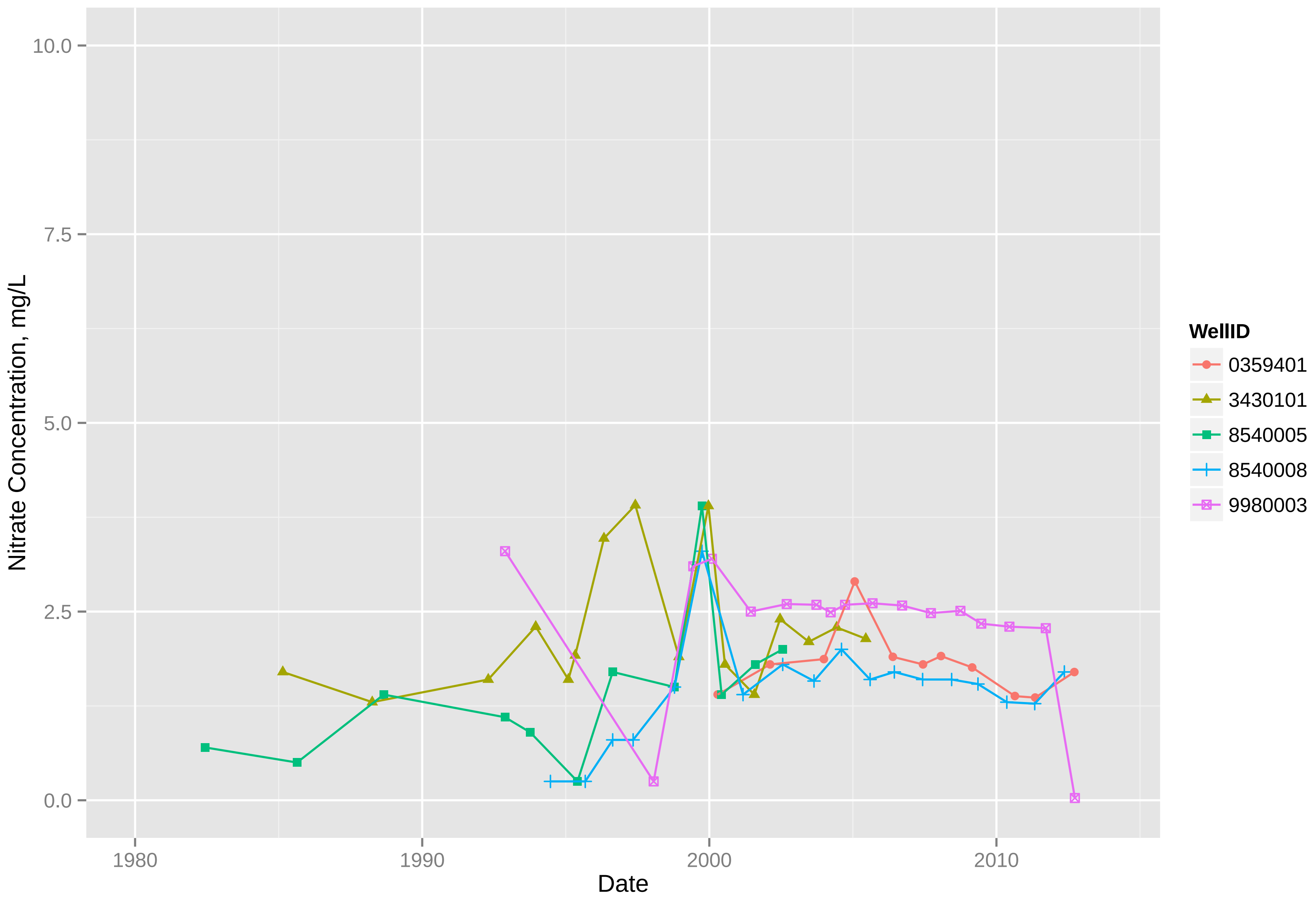
Figure 13. Nitrate Times Series
Max Nitrate 4 to 5 mg/L

PgG



Non−detect values plotted at half the Method Reporting Limit value

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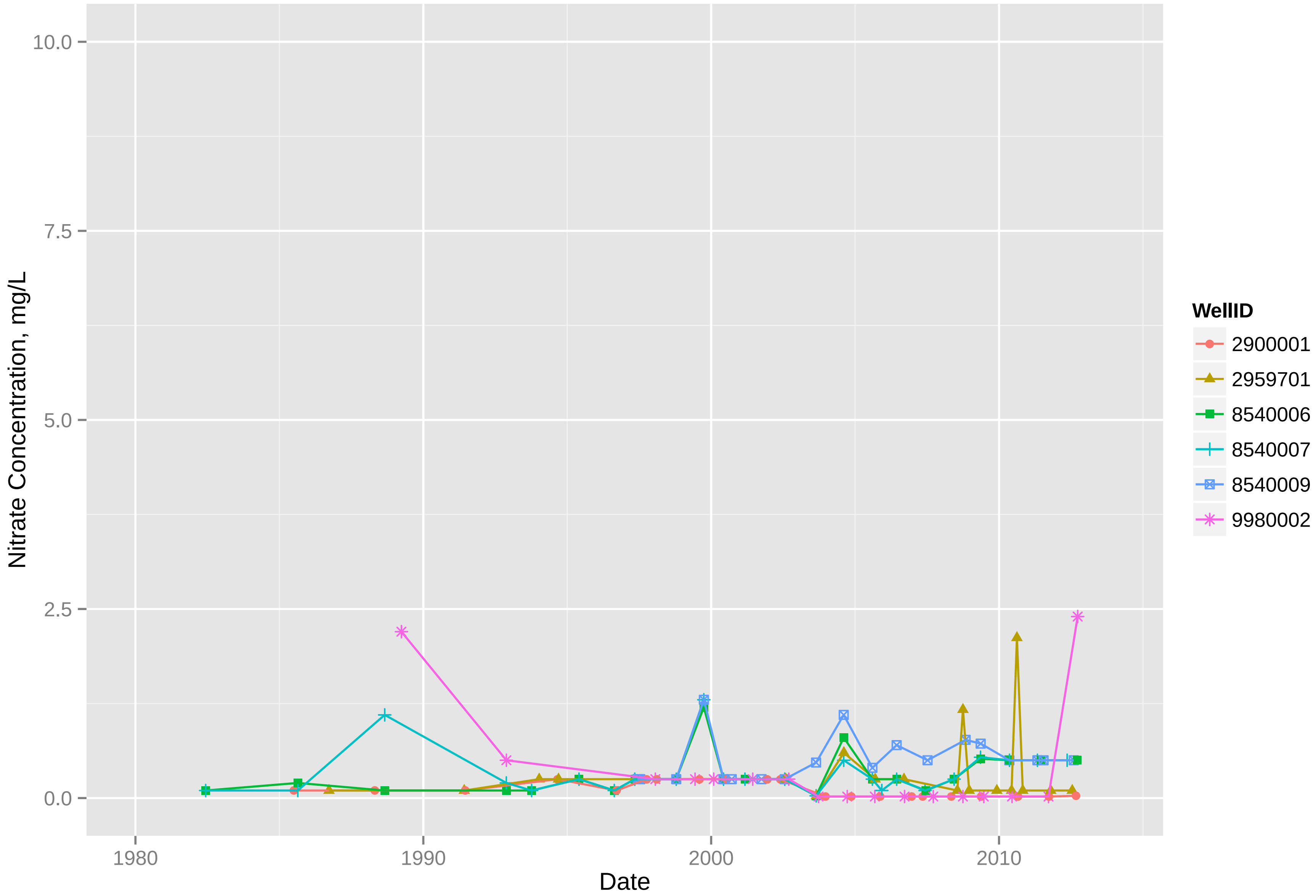
Figure 14. Nitrate Times Series
Max Nitrate 2 to 4 mg/L



Non−detect values plotted at half the Method Reporting Limit value

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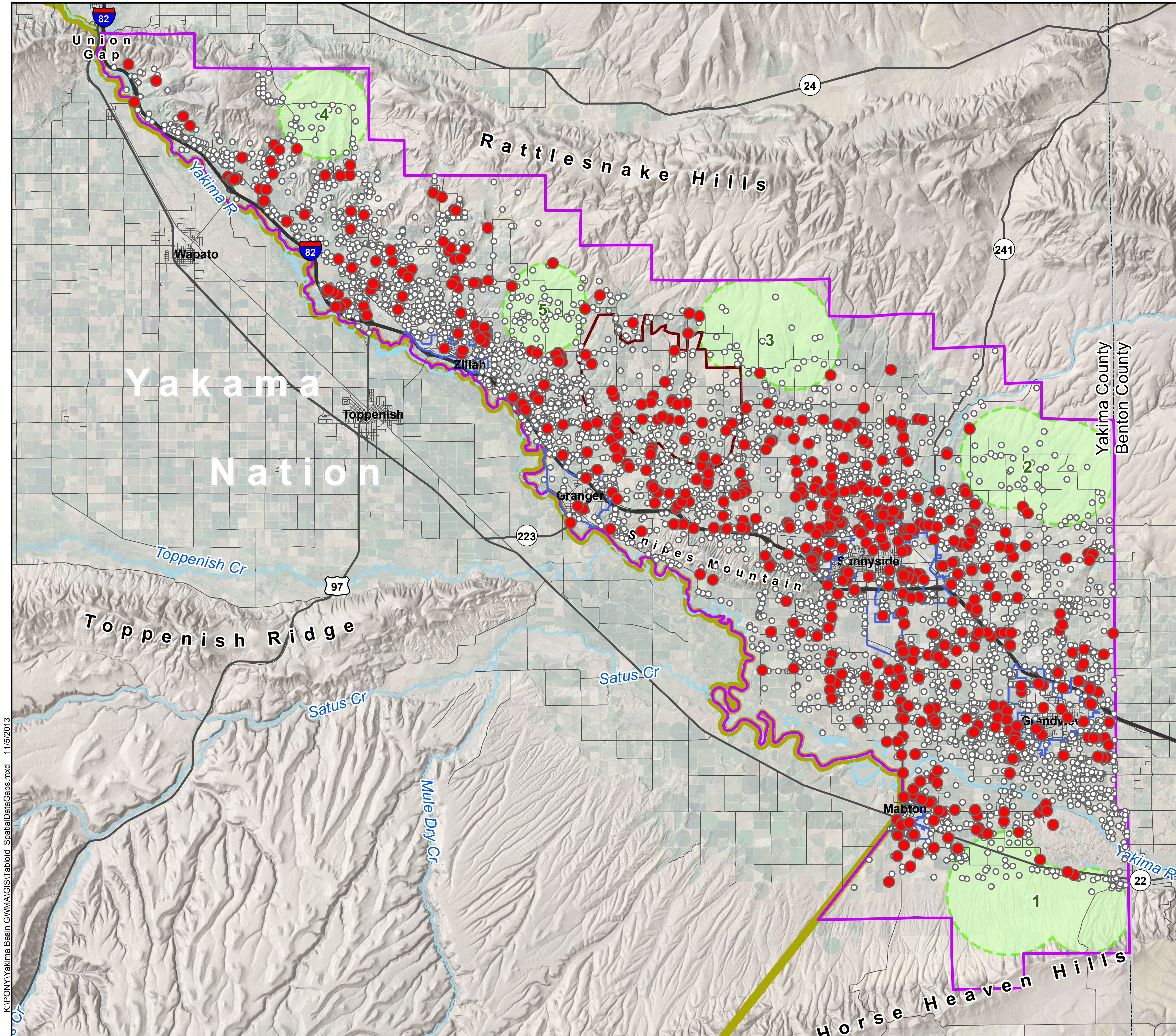
Figure 15. Nitrate Times Series

Max Nitrate <2 mg/L

Figure 16
Spatial Data
Gaps in Nitrate Data



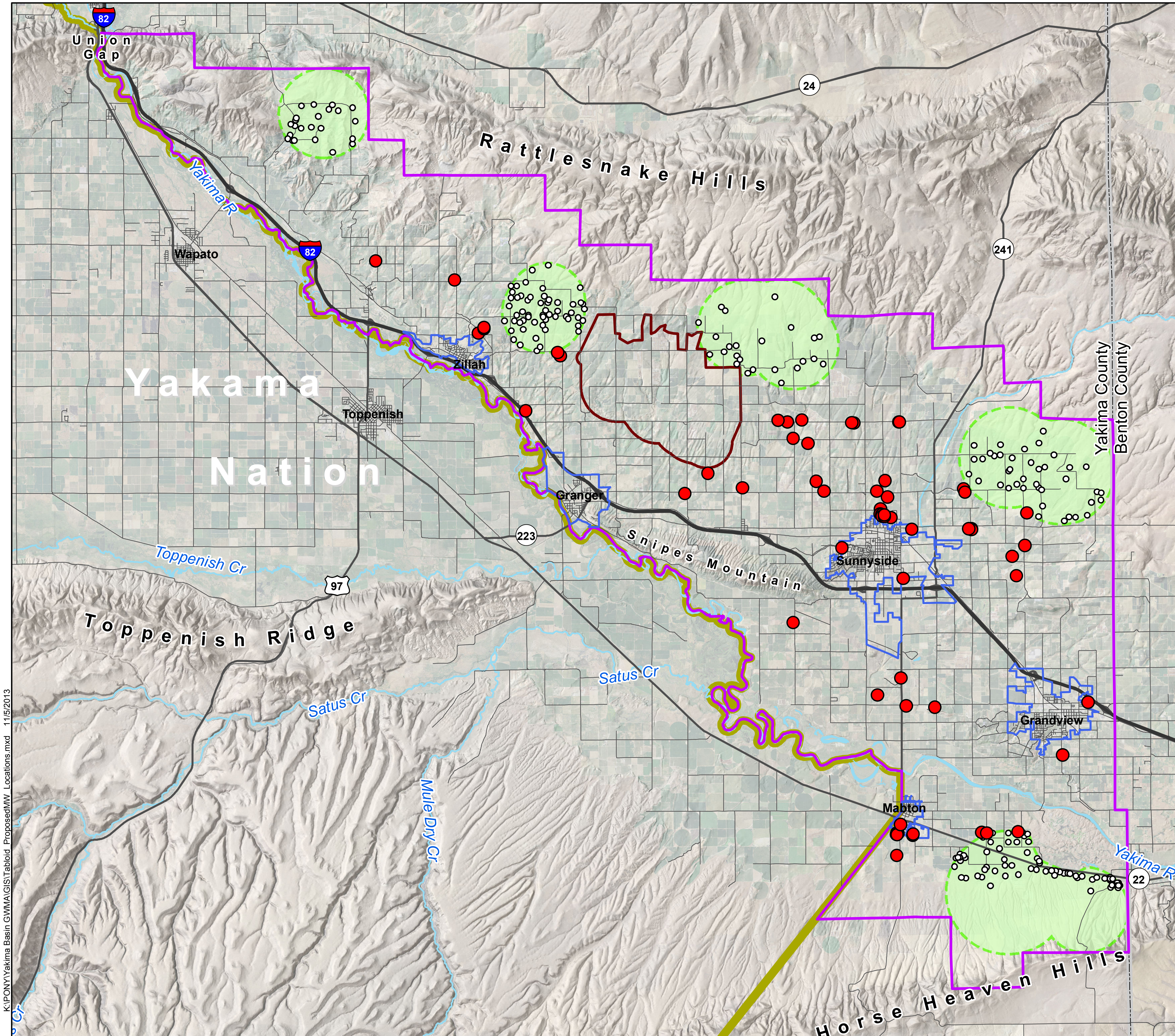


Figure 17

Proposed Monitoring Locations for Spatial Data Gaps, Trends and Hot Spots

PgG

Proposed Monitoring Locations

- Wells Located in Spatial Data Gaps
- Wells with Maximum Nitrate Concentration >20.0 mg/L (Hotspots)
- Spatial Data Gaps
- Water System Service Areas (from WADOH)
- GWMA Boundary
- EPA Dairy Cluster Buffer Boundary
- Yakama Nation Boundary (from Yakima County)

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